

FORECASTING THE SUPPLY OF WATER FOR THE SUMMER FROM THE DEPTH OF SNOW.

By ALEXANDER G. MCADIE.

In the "Journal of Electricity, Power and Gas," March 25, 1911, the writer gave a résumé of the work done in measuring depth of snow at Summit, Placer County, Cal., elevation 7,017 feet. The article has attracted so much attention and is of such general interest, not only to the engineering profession of the State, but to farmers, stockmen, and water users of every kind, that it has been thought advisable to rewrite and enlarge the paper, bringing the records down to date.

Records of the depths of snow and rain have been maintained at the point named since 1870 through the cooperation of the Southern Pacific Railroad Co. and the Weather Bureau. The station is the highest on the railroad, the culminating point in the long stretch of snowsheds, some 40 miles in all, so well known to travelers on the overland route, between Truckee and Blue Canyon.

The snow problem is an ever-present one, always difficult to solve, and much remains to be done regarding proper methods of determining the water equivalent for given snow depths. The tables given below, however, are homogeneous and possess the merit of having been made at the one site and under one system for a period of 33 years. Within the last two years, owing to fire and removal of the station, the depth of snow has been measured at a point about 500 yards west. The data used since 1907 are the depths reported daily to the Weather Bureau office in San Francisco.

In the Monthly Weather Review for June, 1910, there was published an article on "Snowfall records at Summit," giving the general facts regarding the records; also a discussion of the method used by Prof. J. N. Le Conte in 1908 for determining the mean rate of melting. It

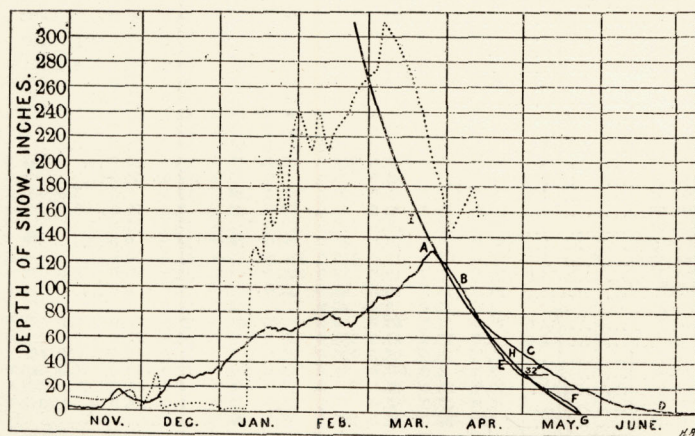


FIG. 1.—Dotted line indicates depth of snow, 1910-11 to April 15, 1911. Solid line indicates average depth, mean of 10 seasons. A, B, E, F, and G indicate average rate of melting.

was found that the curves were extremely irregular for the 11 different seasons considered, up to March 1, but fairly smooth after that date. Prof. Le Conte obtained an average curve showing the mean depth of snow on the ground at Summit. The curve is reproduced (see fig. 1) and the data for the present season added, as shown by the dotted line. In many ways the present season, July 1, 1910, to June 30, 1911, is one of the most remarkable on record. It followed a season when there was less snow in the mountains than had been known for 40 years. Up

to January 9, 1911, the present season was phenomenally dry and the snowfall a negligible quantity. Then there occurred a rapid change to the other extreme and the snow fell almost steadily until January 27, when there was approximately 17 feet on the ground. February was a month of moderate snowfall, also moderate melting.

The total decrease was only 13 inches. During the first week in March 90 inches of snow were added. Before

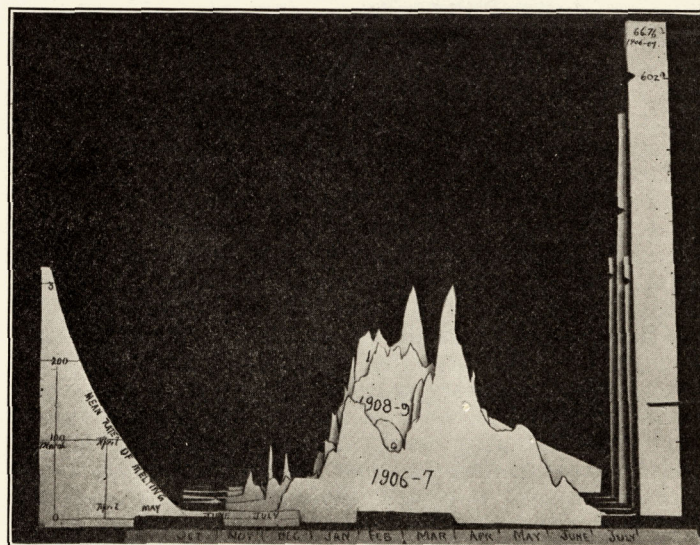


FIG. 2.—Model showing seasonal depth of snow.

the middle of the month a total depth of 305 inches was recorded. Then followed a long period of fair weather, permitting a rapid and nearly uniform rate of melting, the depth decreasing at the rate of about 8 inches per day. It was noticeable, though, that the melting was less rapid as the depth decreased, although with the natural increase in the length of the day and the approach of warmer weather the contrary might have been expected. Without doubt the packing process plays an important part and all measurements of depth and of melting must be corrected for this factor. The writer once made some approximate measurements of the water content of snow at the point under discussion. Samples of snow were taken from the top and the bottom of the snow bank, which had a depth of about 12 feet. Melting the samples, it was found that it required about 20 inches of the loosely packed snow at the top to make 1 inch of water, while of the more compact, almost slushy snow at the bottom, it required only 4 inches to make 1 inch of water.

In the diagram (fig. 1) the dotted lines show the depth of snow on the ground for the current season to April 15. The solid line represents the mean depth of snow and the curve marked ABEFG is the mean rate of melting, from March 1 to May 26, as determined by Le Conte.

We have also made use of the design (fig. 2) shown for comparing the actual curve of melting for any given season with the mean curve, so that we may determine the probable date of the snow's disappearance. The design consists of a wooden base 18 by 7 by $\frac{1}{2}$ inches, with reinforced half-inch pieces at suitable intervals. Small grooves are cut in the base plate and in these are inserted pieces of bristol cardboard, cut to represent the depth of the snow. The vertical scale is 40 to 1 and the horizontal scale approximately an inch and a half to the month. As there is practically no snowfall of importance during

July, August, and September, the models begin on October 1. March 1 falls about the middle of the design, and we thus have on the left side of the design the snowfall of winter, while on the right side we have the snowfall of the spring months. In the first groove there is inserted a card showing the mean rate of melting. This can be slid along in the groove and the rate compared with the profile of any given year. While this is not strictly the true rate of melting for the whole year, it affords an approximate measure of the rate of melting under normal conditions. Snowstorms are shown by peaks which indicate both the added depth and the rate of melting in the intervals of fair weather. At the right side of the frame vertical strips of cardboard show the total precipitation for the season and by suitable notches how much of the precipitation was snow. The whole design enables one to readily compare the depth of snow on the ground at any given date with the amount during previous seasons.

Summit is an interesting station for snowfall work, because 86 per cent of the precipitation falls in the form of snow, and most of the rain falls during July, August, and September, practically before the snow cover amounts to anything. It is true that occasionally there will come a warm rain in January or February, and such a condition rapidly reduces the depth of snow. The greatest factor, however, in reducing the depth is probably the wind, and under certain conditions when the dry surface air moves rapidly from the northeast the decrease by evaporation is considerable.

Card profiles can be cut to show the run-off as determined by stream measurements and these inserted to show the relation between run-off and melting. Gaugings of the Truckee River have been made by the United States Reclamation Service for the Truckee-Carson project, and as soon as these are available they will be studied in connection with the snow depths.

By means of the design and the tables we have ventured the statement that the season will be a late one in the mountains, so far as travel is concerned. The snow will probably continue in the higher passes until the middle of July, and there is little likelihood that the snow will be off the ground at elevations of 6,000 to 7,000 feet before the middle of June. Also there is every reason for anticipating from the present depth of the snow cover an abundant supply of water lasting well into the fall. Engineers, farmers, and stockmen may confidently expect sufficient water for their purposes throughout the coming summer.

Total precipitation, including snow, at Summit, Placer County, Cal., for the years 1870 to 1911.

[Elevation, 7,017 feet.]

Seasons.	July.	August.	September.	October.	November.	December.	January.	February.	March.	April.	May.	June.	Seasonal.	Year.	Annual.		
1870-71.							7.60	7.55	4.05	4.00	0.31	0.89	1871	60.60		
1871-72.	0.00	0.00	0.30	0.40	8.50	27.00	4.00	16.10	5.90	2.50	0.30	0.00	68.10	1872	37.90		
1872-73.			0.00	0.00	0.00	6.00	2.31	16.20	6.08	2.55	2.11	0.00	35.22	1873	40.95		
1873-74.	0.03	1.00	0.00	0.00	0.00	11.70	5.00	0.00	0.00	2.00	3.60	T.	22.33	1874	18.85		
1874-75.			0.00	0.00	3.80	3.60	8.85	8.15	1.12	4.80	2.80	1.46	2.55	28.13	1875	33.86	
1875-76.			0.00	0.00	0.00	12.23	6.50	7.25	14.65	8.70	13.80	2.60	1.60	T.	157.33	1876	46.90
1876-77.	1.21	1.00	5.56	2.98	6.50	2.20	8.90	6.99	3.44	4.54	3.75	1.12	27.29	1877	26.73		
1877-78.	0.00	0.00	0.30	0.55	3.34	30.10	10.50	3.05	2.40	1.60	0.00	0.00	33.54	1878	73.67		
1878-79.			0.00	0.00	0.00	1.60	13.65	8.70	21.05	4.52	2.55	1.10	54.71	1879	32.69		
1879-80.	0.00	0.00	0.00	0.00	4.20	5.60	13.30	6.60	7.50	8.90	30.40	3.60	0.00	10.10	1880	64.50	
1880-81.	0.80	0.00	0.00	0.00	0.00	5.60	6.20	7.50	4.60	1.50	1.00	0.05	5.00	22.65	1881	30.95	
1881-82.	0.00	0.00	0.00	0.00	3.10	3.05	9.05	7.40	9.00	19.30	3.25	0.60	0.00	55.35	1882	62.12	
1882-83.	0.00	0.00	0.75	12.95	3.95	4.92	1.00	2.60	7.70	3.40	3.42	0.00	40.69	1883	23.57		
1883-84.	0.00	0.00	0.10	0.95	1.20	3.20	7.60	12.70	9.10	12.60	6.80	4.04	52.29	1884	60.47		
1884-85.	0.00	1.10	3.13	0.00	0.00	9.40	1.40	0.58	1.10	4.58	1.00	8.00	22.39	1885	25.41		
1885-86.	0.00	0.00	0.05	0.00	13.60	3.00	13.90	1.40	7.80	6.40	0.95	0.00	47.10	1886	41.00		
1886-87.	0.00	0.00	0.00	0.30	1.70	5.75	6.25	20.70	1.40	5.80	0.95	1.60	47.25	1887	49.97		

¹ Partly interpolated.

Total precipitation, including snow, at Summit, Placer County, Cal., for the years 1870 to 1911—Continued.

Seasons.	July.	August.	September.	October.	November.	December.	January.	February.	March.	April.	May.	June.	Seasonal.	Year.	Annual.
1887-88...	1.10	T.	T.	0.07	1.50	11.60	9.20	1.29	8.05	2.30	1.04	3.72	38.87	1888	36.55
1888-89...	3.51	28	0.00	0.00	1.90	5.28	1.00	1.50	9.55	1.90	6.30	0.22	31.42	1889	51.42
1889-90...	0.00	0.00	0.00	5.65	6.80	18.50	19.20	11.60	14.00	2.60	0.25	0.00	78.60	1890	55.05
1890-91...	0.00	0.00	0.00	0.00	0.00	7.40	1.50	1.38	5.10	4.60	1.10	0.00	21.08	1891	26.13
1891-92...	0.00	0.00	0.00	0.00	3.30	11.90	4.00	3.40	7.40	4.50	6.30	0.00	38.25	1892	44.70
1892-93...	0.00	0.00	0.00	0.60	8.80	9.50	7.90	10.80	14.50	9.20	0.00	0.00	61.30	1893	52.30
1893-94...	0.00	0.00	0.00	0.30	3.60	6.00	15.50	15.25	3.40	4.30	2.40	0.00	50.75	1894	69.75
1894-95...	0.00	0.00	0.00	2.90	1.00	24.50	25.80	4.20	4.70	2.50	2.40	0.00	68.50	1895	49.50
1895-96...	0.00	0.00	0.00	0.00	1.40	8.30	10.50	0.70	9.70	18.20	5.40	0.00	54.40	1896	62.43
1896-97...	1.21	0.02	0.40	0.90	12.30	4.10	4.05	14.35	18.00	1.25	0.00	0.70	56.28	1897	47.73
1897-98...	0.00	0.00	0.00	0.03	2.50	2.65	4.20	4.00	7.10	5.20	0.80	2.90	31.28	1898	31.40
1898-99...	0.00	0.00	0.00	0.40	2.50	3.60	12.70	5.20	15.75	1.75	3.60	0.70	50.20	1899	73.80
1899-1900...	0.00	0.00	0.00	16.05	9.15	7.90	5.25	4.75	8.15	4.80	3.97	0.50	61.52	1900	42.52
1900-1901...	25	T.	0.95	3.50	6.90	3.50	11.30	14.20	4.50	5.50	1.00	0.00	51.60	1901	49.60
1901-2...	0.00	0.00	0.00	4.20	4.70	2.80	4.00	16.30	8.90	3.00	1.10	0.30	46.70	1902	49.00
1902-3...	0.00	0.00	0.00	2.30	7.50	4.60	10.50	3.30	11.10	1.70	0.80	T.	42.70	1903	40.50
1903-4...	0.00	0.00	0.00	1.20	11.20	8.0	4.20	30.40	21.30	3.90	0.23	0.05	73.28	1904	76.54
1904-5...	0.04	0.03	4.58	1.90	1.33	8.60	5.55	7.00	10.70	2.90	3.70	1.40	47.71	1905	43.85
1905-6...	T.	0.00	0.00	0.60	7.80	3.70	14.10	9.30	11.75	2.60	4.12	10.10	56.57	1906	57.55
1906-7...	T.	1.00	0.32	2.12	2.04	10.10	13.50	4.38	27.36	2.66	3.06	2.22	66.76	1907	66.48
1907-8...	12	T.	0.68	2.52	4.0	10.20	3.50	4.00	10.20	1.14	3.70	0.44	36.78	1908	33.28
1908-9...	0.00	0.76	1.20	1.54	3.60	2.70	29.44	8.94	4.60	4.0	1.10	0.88	55.16	1909	60.62
1909-10...	0.00	0.00	0.72	1.66	4.58	8.30	8.60	5.10	4.90	0.68	0.53	0.00	35.15	1910	33.91
1910-11...	1.16	0.00	2.82	0.60	5.46	4.08	28.90	5.30	10.63	0.00	0.00	0.00	47.37	1911	47.12
Mean...	0.19	0.11	0.46	2.30	4.01	7.31	9.27	7.78	8.96	4.50	2.09	0.62	47.37	...	47.12

¹ Partly interpolated.

Snowfall at Summit, Placer County, Cal., for the years 1878 to 1911.

[Elevation, 7,017 feet.]

Years.	July.	August.	September.	October.	November.	December.	January.	February.	March.	April.	May.	June.	Annual.
1878...							100.0	115.0	30.0	24.0	16.0		445.5
1878-79...		4.2	12.1	8.0	6.0	77.5	57.0	209.0	45.2	25.5	1.0		753.0
1879-80...		0	42.0	56.0	133.0	66.0	75.0	89.0	298.0	24.0			153.5
1880-81...				5.0	62.0	45.0	16.0	15.0	10.0				492.5
1881-82...		6.0	26.0	30.5	43.0	65.5	90.0	193.0	32.5	6.0			299.0
1882-83...		7.5	27.5	39.5	49.5	70.0	26.0	72.0	34.0	33.0			481.5
1883-84...			9.5	12.0	32.0	76.0	127.0	91.0	126.0	2.0	6.0		202.0
1884-85...		11.0	21.0		94.0	14.0	5.0	1.0	38.0	10.0	8.0		462.5
1885-86...				136.0	30.0	131.0	14.0	78.0	64.0	5.0			422.0
1886-87...				31.0	17.0	34.0	56.0	207.0	14.0	58.0	5.0		345.0
1887-88...				15.0	116.0	92.0	7.0	80.5	21.0	4.0	9.5		261.0
1888-89...				16.5	39.0	10.0	15.0	95.5	19.0	63.0	3.0		776.0
1889-90...				61.0	185.0	192.0	116.0	147.0	26.0	25.0			335.0
1890-91...					74.0	15.0	138.0	51.0	46.0	11.0			380.5
1891-92...				5.0	119.0	40.0	34.0	74.0	45.0	63.0	2.0		634.0
1892-93...				6.0	88.0	95.0	79.0	108.0	145.0	92.0	21.0		511.0
1893-94...		3.5	3.0	36.0	60.0	155.0	152.5	34.0	43.0	24.0			685.0
1894-95...		5.0	29.0	10.0	245.0	258.0	42.0	47.0	25.0	24.0			544.0
1895-96...		2.0	0	14.0	53.0	105.0	7.0	97.0	182.0	54.0			560.5
1896-97...		4.0	9.0	123.0	41.0	40.5	143.5	180.0	12.5	0	7.0		262.0
1897-98...		5	25.0	26.5	42.0	40.0	30.0	52.0	8.0	29.0	9.0		481.0
1898-99...			34.0	25.0	36.0	127.0	52.0	157.5	17.5	32.0			406.0
1899-1900...			89.0	29.0	79.0	41.0	38.0	79.0	42.0	9.0			440.5
1900-1901...		1.5	21.0	60.0	15.0	113.0	120.0	45.0	55.0	10.0			373.0
1901-2...		14.0	22.0	12.0	10.0	19.0	163.0	39.0	30.0	11.0	3.0		407.0
1902-3...			23.0	75.0	46.0	85.0	32.0	111.0	27.0	8.0			434.0
1903-4...			1.0	22.0	8.0	42.0	172.0	148.0	39.0	2.0			375.0
1904-5...		3.0	14.0	12.0	66.0	50.0	64.0	107.0	23.0	34.0	2.0		262.0
1905-6...		5.0		78.0	37.0	138.0	82.0	109.0	26.0	36.0	3.0		602.0
1906-7...			T.	18.0	98.5	136.0	26.0	265.0	21.0	19.0	19.0		342.0
1907-8...			T.	4.0	101.0	35.0	45.0	102.0	12.0	37.0	1.0		
1908-9...			T.	10.0	36.0	27.0	226.0	82.0	46.0	4.0	11.0		
1909-10...				9.0	59.0	83.0	86.0	51.0	42.0	8.0	4.0		
1910-11...				3.0	30.0	33.0	293.0	53.0	99.0	0.00	0.00		
Mean...		2.1	15.0	35.1	67.3	89.7	73.7	94.0	47.1	20.1	2.3		443.5

Depth of snow on ground, in inches, at Summit, Placer County, Cal., for the years 1906 to 1911.

[Records for the year 1906 destroyed by fire Apr. 13, 1906.]

Day of month.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1907.												
1.....	45	137	104	240	115	68	14	(1)	(1)			
3.....	63	127	115	230	113	60	11	(1)	(1)			
5.....	80	120	123	230	114	51	11	(1)	(1)			

*Depth of snow on ground, in inches, at Summit, Placer County, Cal.,
for the years 1906 to 1911—Continued.*

[illegible]

¹ Several feet snow in canyons.

* Several feet snow on highest peaks.